F-8033

BEARING APPARATUS AND PRODUCING METHOD THEREOF

REFERENCE TO RELATED APPLICATION

This is a divisional application and hereby incorporates by reference the

5   entire disclosure of application Serial No. 09/902,245, filed July 10, 2001.

BACKGROUND OF THE INVENTION

The present invention relates to a bearing apparatus and a producing

method thereof, and more particularly, to a bearing apparatus and a producing

10   method thereof which are preferably used for a hub unit for a vehicle such as an

automobile.

A hub unit for a vehicle will be explained. The hub wheel has a hollow

shaft. An inner ring of a rolling bearing is mounted to an outer periphery of the

hollow shaft by press-fit. A shaft end of the hollow shaft is caulked on the outer

15   end surface of the inner ring by bending the shaft end outwardly in a diametrical

direction. The bearing is prevented from slipping off from the hollow shaft by this

caulked portion. A pre-load is applied to the inner ring of the bearing by this

caulking.

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A load is applied to the hollow shaft by the pressure-fit of the inner ring of the bearing. The hollow shaft is formed around its outer periphery with a hardened layer due to heat by quenching or the like in order that the hollow shaft has the structure that can bear the load. On the other hand, the shaft end of the hollow shaft remains in a stage of being caulked on the outer end surface of the inner ring, i.e., the shaft end is not hardened.

A range of the hardened layer formed on the outer periphery of the hollow shaft is limited to a certain degree.

However, in the range where the hardened layer is formed, a position of the caulked side end portion in the axial direction is not clearly defined. Thus, when it is processed to be hardened, the position of the caulked side end portion of the hardened layer in its add is prone to be an incorrect position closer to an outer end or to inner end in the axial direction from the limited range.

If the position of the end portion in the axial direction of the hardened layer is positioned incorrectly with respect to the hollow shaft, a gap may be generated between an inner peripheral surface of the inner ring and an outer peripheral surface of the hollow shaft caulked on the outer end surface thereof in some cases. This gap deteriorates creep resistance.

Therefore, a caulking auxiliary jig is previously inserted on the side of the inner periphery of the hollow shaft before caulking, thereby preventing the gap from being generated. Further, after the caulking, the inner periphery of the

hollow shaft is again worked. Such a gap-preventing operation of the hollow shaft increases the number of producing steps and cost of the hub unit.

SUMMARY OF THE INVENTION

Thus, it is a main object of the present invention to provide a bearing

5   apparatus of a hub unit, and the like, for a vehicle, capable of appropriately managing a position of an end portion, in the axial direction, of a hardened layer formed on an outer periphery of a hollow shaft.

Other objects, features and merits of the present invention will be apparent from the following description.

10   The present invention is, in sum, described as follows. A bearing apparatus of the present invention includes a hollow shaft provided around its outer peripheral surface with a bearing fitting region, and a rolling bearing having an inner ring fitted around the bearing fitting region of the hollow shaft. A shaft end of the hollow shaft is bent outwardly in a diametrical direction, thereby being

15   caulked on an outer end surface of the inner ring of the rolling bearing.

The bearing fitting region has a hardened layer in its region from an inner end surface corresponding position of the inner ring of the rolling bearing to a portion before an outer end surface corresponding position. The bearing fitting region further has a non-hardened layer in its region from the portion before the

20   outer end surface corresponding position of the inner ring to the shaft end of the hollow shaft.

A position of a caulked side end portion of the hardened layer is defined based on the following relational expression (1):

$$((A - C - D) Y/E) \leq X < (A - C)... (1)$$

wherein A represents a width in the axial direction of the inner ring, C represents a chamfering length in the axial direction in the outer end surface of the caulked side of the inner ring, D represents a chamfering length in the axial direction in an outer end surface of the inner ring, E represents a thickness of the hollow shaft, X represents a distance from a position of the chamfering length D to the caulked side end portion of the hardened layer, and Y (<E) represents a hardening treatment depth.

With this defining expression, appropriate hardening treatment can be carried out by applying concrete numerical values to the respective length in the axial direction of the inner ring and the thickness of the hollow shaft. Further, it is possible to reduce the number of steps and time of the producing operation of the bearing apparatus, such as a hub unit, and to enhance the productivity.

In the present invention, preferably, the hollow shaft is a hub wheel, the rolling bearing is a double row angular contact ball bearing with vertex of contact angles outside of bearing or a double row tapered roller bearing with vertex of contact angles outside of bearing.

These and other objects, as well as advantages, of the invention will become clear by the following description of preferred embodiments of the

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invention with reference to the accompanying drawings, wherein like components

are indicated by the same numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a vertical sectional view of a hub unit before caulking according

5   to a preferred embodiment of the present invention;

Fig. 2 corresponds to Fig. 1 and is a vertical sectional view after caulking;

Fig. 3 is an enlarged sectional view of an essential portion in Fig. 1;

Fig. 4 is an enlarged sectional view of an essential portion according to

another preferred embodiment of the invention; and

10   Fig. 5 is an enlarged sectional view of an essential portion according to

another preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A hub unit for a driving wheel of a vehicle as a bearing apparatus

according to a preferred embodiment of the present invention will be explained

15   with reference to Figs.1 to 3.

A hub unit 10 includes a hub wheel 11 and a bearing 12.

The hub wheel 11 includes a flange 13 and a hollow shaft 14. A wheel (not

shown) is mounted to the flange 13. The hollow shaft 14 has a bearing fitting

region comprising a large-diameter outer peripheral surface and a small-diameter

20   outer peripheral surface. The bearing 12 is fixed to the bearing fitting region.

A shaft end 14a of the hollow shaft 14 is bent outwardly in a diametrical

direction from a state shown in Fig. 1 by rolling caulking and is plastically

deformed. With this operation, the shaft end 14a is caulked on an outer end

surface of an inner ring 15 of an angular contact ball bearing 12 as shown in Fig.

5   2.

The bearing 12 is a double row angular contact ball bearing with vertex of

contact angles outside of bearing as one example of an inclined rolling bearing.

The bearing 12 includes an inner ring (first inner ring) 15 having a single orbit

which is fitted around the small-diameter outer peripheral surface of the bearing

10   fitting region of the hollow shaft 14, a single outer ring 16 having two rows of

orbit grooves, a plurality of balls 17 arranged in two rows, and two cages 18.

The large-diameter outer peripheral surface of the bearing fitting region of

the hollow shaft 14 of the hub wheel 11 is one inner ring (second inner ring) of

the bearing 12. An inner ring of a common single raw angular contact ball bearing

15   is used as the inner ring 15 as it is.

The outer ring 16 is provided around its outer periphery with a flange 19.

The caulking operation of the hub unit 10 will be explained.

The shaft end 14a of the hollow shaft 14 is caulked on the outer end

surface of the inner ring 15 from a state shown in Fig. 1 to a state shown in Fig. 2.

20   Thereafter, the hub unit 10 is mounted between a drive shaft 20 and a knuckle (or

carrier) 21 of the vehicle. That is, the hollow shaft 14 of the hub wheel 11 is

spline-fitted into the drive shaft 20 and coupled by a nut 22. The flange 19 of the

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outer ring 16 of the bearing 12 is non-rotatably coupled to the knuckle (or carrier) 21 by means of a bolt 23.

Features of the present embodiment will be explained with reference to Fig. 3.

The outer end surface of the inner ring 15 of the bearing 12 has an inner peripheral angle portion 15a. The inner peripheral angle portion 15a is roundly chamfered, e.g., from a center O through 1/4 circumference of radius of curvature C. An inner end surface in the inner ring 15 of the bearing 12 has an inner peripheral angle portion 15b. The inner peripheral angle portion 15b is roundly chamfered, e.g., from the center O through 1/4 circumference of radius of curvature C.

The inner peripheral angle portion 15a has a chamfering-start point 15c. The chamfering-start point 15c is a bending-start point when the shaft end 14a of the hollow shaft 14 is bent outwardly in a diametrical direction around the outer end surface of the inner ring 15. The inner peripheral angle portion 15b of the inner ring 15 has a chamfering-start point 15d.

In the bearing fitting region of the hollow shaft 14, hardened layers 24a and 24b are formed from the large-diameter outer peripheral surface to the small-diameter outer peripheral surface thereof as shown with cross hatchings in the drawings.

The hardened layer 24b formed on the small-diameter outer peripheral surface into which the inner ring 15 of the bearing 12 is fitted is hardened through

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a required depth from its surface by thermal treatment such as quenching in a

region from a position (first corresponding position) corresponding to an inner

end surface of the inner ring 15 to a portion before a position (second

corresponding position) corresponding to an outer end surface.

5   A range of the hollow shaft 14 from its portion before the second

corresponding position to the shaft end 14a of the hollow shaft 14 is non-hardened

layer. With this layer, it is possible to caulk the shaft end 14a with respect to the

outer end surface of the inner ring 15 outwardly in a diametrical direction.

Here, the portion before the second corresponding position is defined as a

10   position (X) of the caulked side end portion of a hardened layer 24.

The position (X) of the caulked portion is defined between the

bending-start point 15c and a position which is determined by a thickness (E) of

the hollow shaft 14 and a fitting region length (A - C - D) of the hollow shaft 14

into the inner ring 15 in the small-diameter outer peripheral surface with respect

15   to at least predetermined hardening treatment depth (Y).

The definition of the position (X) of the caulked side end portion of a

hardened layer 24b will be explained in detail.

A length in the axial direction of the inner ring 15 of the angular contact

ball bearing 12 is defined as (A), a chamfering length in the axial direction of the

20   outer end surface of the inner ring 15 is defined as (C), a chamfering length in the

axial direction of the inner end surface of the inner ring 15 is defined as (D), an

axial thickness of the hollow shaft 14 is defined as (E), a distance from the

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position of the chamfering length (D) in the inner ring 15 to the caulked side end portion of the hardened layer 24b is defined as (X), and a hardening treating depth is defined as (Y). However, when the inner peripheral surface of the hollow shaft 14 is formed with female spline as in this embodiment, the axial thickness (E) is a thickness from the outer periphery of the hollow shaft 14 to the bottom of the tooth of the female spline.

The position (X) of the caulked side end portion of the hardened layer 24b is defined in a range shown with the following expression (1).

$$((A - C - D) \, Y/E) \le X < (A - C)... (1)$$

In the expression (1), the left side term $(A - C - D) \, Y/E$ is based on a condition that the fitting region length between the hollow shaft 14 and the inner ring 15 when the hollow shaft 14 is caulked and deformed is defined as (A - C - D), the axial thickness of the hollow shaft 14 is defined as (E)mm, the position of the caulked terminal end of the hardened layer 24b is defined as (X) mm, and the hardening treatment depth of the hardened layer 24b is defined as (Y) mm. In this case, according to experiments and calculations by the present inventors, an expression $(A - C - D):E = X:Y$ is established. From this expression, the relation $(A - C - D) \, Y/E$ is established.

(Table 1)

Desk checking			Bearing (1)	Bearing (2)
	Size mm	A	18	22
		C	4.5	4.5
		D	2.5	2.5
		E	5	3.5
		Y	2.5	2.5
	X (min.)	(A-C-D)*Y/E	5.5	10.7
	X (max.)	A-C	13.5	17.5
	X (min.)+D		8.0	13.2
	X (max.)+D		16.0	20.0
Result of test On interface between inner ring and shaft O: no clearance exists x: clearance exists	X + D mm	0	x	x
		2	x	x
		3	x	x
		5	x	x
		8	O	x
		10	O	x
		13	O	O
		15	O	O
		17	x	O
		20	-	O
		22	-	x

In Table 1, "Result of test" shows the result after changing the value of X

by each size (A, C, D, E, and Y) of the bearing shown in "Desk checking." X(min)

represents the minimum value of X, and X(max) represents the maximum value of

X. The bearings (1) and (2) are only different in size, and they are employed in the test in order to obtain the relational expression (1) that satisfies in the cases of bearings with different sizes.

That is, when the hardened layer 24b is formed on the hollow shaft 14, if the length in the axial direction of the hollow shaft 14 is long, the treatment width of the hardened layer 24b in the axial direction becomes long correspondingly. If the shaft thickness (E) of the hollow shaft 14 is increased, the load bearing capacity from the inner ring 15 is increased and thus, the thickness (Y) of the hardened layer 24b may be shallow correspondingly.

Therefore, from the left side term $(A - C - D) Y / E$ of the above expression (1), the position (X) of the caulked side end portion of the hardened layer 24b is proportional to the hardening treatment depth (Y) and the fitting region length $(A - C - D)$ between the hollow shaft 14 and the inner ring 15, and is inversely proportional to the shaft thickness (E) of the hollow shaft 14.

From the above reasons, it is possible to harden the hollow shaft 14 by defining the position (X) of the caulked side end portion of the hardened layer 24b in the region of the expression (1).

The hollow shaft 14 of the hub wheel 11 has low load bearing capacity of the inner ring 15. Therefore, the position (X) of the caulked side end portion of the hardened layer 24b is important. Thus, the hollow shaft 14 by defining the position (X) of the caulked side end portion of the hardened layer 24b is defined as a position defined based on the length in the axial direction and axial thickness

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of the hollow shaft 14 which is caulked and deformed in shortest. With this

design, it is possible to optimize the caulking load of the shaft end of the hollow

shaft 14 with respect to the outer end surface of the inner ring 15, and to optimize

the load bearing capacity of the inner ring 15.

5   From the above reasons, in the small-diameter outer peripheral surface of

the hollow shaft 14, the range from the position (X) to the shaft end is

non-hardened layer. Therefore, at the time of caulking, no gap is generated

between the small-diameter outer peripheral surface and the inner peripheral

surface of the inner ring 15 in that range, and the hollow shaft 14 is caulked with

10   respect to the outer peripheral surface of the inner ring 15. The range from the first

corresponding position to the position (X) is formed as the hardened layer 24.

Therefore, no gap is generated between the small-diameter outer peripheral

surface and the inner peripheral surface of the inner ring 15 in that range, and the

hollow shaft 14 is caulked with respect to the outer peripheral surface of the inner

15   ring 15. As a result, the hub unit 10 has excellent creep resistance.

When the hub unit 10 is produced, it is unnecessary to previously insert

the caulking auxiliary jig into the inner diameter side of the hollow shaft 14 to

prevent a gap from being generated, and to work the inner diameter of the hollow

shaft 14.

20   For these reasons also, the structure of the hub unit 10 is suitable for mass

production in which the number of steps and time of the production can be

reduced.

In the above case, if the axial chamfering length of the inner peripheral angle portion of the outer end surface of the inner ring 15 is added to the correlation in the definition of the shortest position of the caulked side end portion of the hardened layer 24b, it is possible to manage the position of the caulked side end portion of the hardened layer 24b more appropriately.

The present invention is not limited to the above embodiment, and various applications of modifications are possible.

(1) According to the present invention, as shown in Fig. 4, the above hardened layer 24b can also be applied to a hub unit in which the first inner ring 15 and the second inner ring 15e have a bearing 12 disposed adjacent thereto in its axial direction. In this case, both the first inner ring 15 and the second inner ring 15e are fitted around the small-diameter outer peripheral surface of the hollow shaft 14. The shaft end of the hollow shaft 14 is caulked on the outer end surface of the first inner ring 15.

(2) In the invention, a double row tapered roller bearing with vertex of contact angles outside of bearing may be used. An inner ring in that case may comprise one inner ring and an inner ring and another inner ring which is integrally formed on an outer peripheral surface of the hollow shaft, or may comprise two inner rings adjacently disposed in the axial direction, like the double row angular contact ball bearing with vertex of contact angles outside of bearing. The above hardened layer 24 can also be applied to a hub unit having the tapered roller bearing with vertex of contact angles outside of bearing.

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(3) The present invention is not limited to the hollow shaft 14 which is hollow in the axial direction, and as shown in Fig. 5, the hardened layer 24b can also be applied to a hub unit having a bottomed shaft 14a.

(4) The present invention is not limited to the driving wheel of a vehicle, and the hardened layer 24b can also be applied to a hub unit for a follower wheel of the vehicle.

(5) An inner periphery of the hollow shaft 14 of the hub wheel 11 is formed with the female spline 14b meshing with male spline formed on an outer periphery of the drive shaft 20 for fitting the drive shaft 20 into the hollow shaft 14.

In order to couple the hollow shaft 14 and the drive shaft 20 to each other with mechanically necessary strength, it is preferable that the spline 14b is formed in the axial direction on the inner periphery of the hollow shaft 14. With this design, an end of the spline 14b is close to the caulked portion. According to this design, in a region close to the caulked portion, the male spline of the drive shaft 20 is prone to be deformed such as to be shrunk in the diametrical direction in such a degree that the male spline of the drive shaft 20 can not be fitted into the female spline easily when the caulked portion is caulked. This deformation could reach 50 mm in the diametrical direction in some cases. To avoid this deformation, the following first and second producing methods are proposed.

In the first producing method, the spline 14b is subjected to a primary working such as spline broach with respect to the inner periphery of the hollow

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shaft 14 before caulking, and the spline 14b on the inner periphery of the hollow

shaft 14 after caulking is subjected to a secondary working such as the spline

broach. In the case of the secondary working, a deformed portion of the spline 14b

formed by the primary working generated during the caulking working is

5   subjected to correcting working such as plastically deformation so that the spline

of the drive shaft 20 can be fitted.

In the second producing method, the inner periphery of the hollow shaft 14

is not formed with the spline 14b before caulking, and the inner periphery of the

hollow shaft 14 is formed with the spline 14b by mechanical working such as

10   spline broach after caulking.

With any of the methods, it is possible to enhance the shape precision of

the spline 14b formed on the inner periphery of the hollow shaft 14 after caulking.

Therefore, it is possible to easily fit the spline formed on the outer periphery of the

drive shaft 20 to the spline 14b.

15   (6) In the present invention, a structure in which the first inner ring 15 and

the second inner ring 15e of the common single row angular contact ball bearing

may be subjected to the spline broach as in the same manner as that of above (5)

with respect to the spline 14b to the inner periphery of the hollow shaft 14 as

partially shown in Fig. 4.

20   While there has been described what is at present considered to be

preferred embodiments of this invention, it will be understood that various

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modifications may be made therein, and it is intended to cover in the appended

claims all such modifications as fall within the true spirit and scope of this

invention.